AN AUTOMATED HAND HYGIENE COMPLIANCE SYSTEM IS ASSOCIATED WITH DECREASED RATES OF HEALTH CARE-ASSOCIATED INFECTIONS

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American Journal of Infection Control ■■ (2018) ■■-■■

Contents lists available at ScienceDirect

American Journal of Infection Control

journal homepage: www.ajicjournal.org

Major Article

An automated hand hygiene compliance system is associated with decreased rates of health care-associated infections

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Key Words:
Catheter-associated urinary tract infections
Central line-associated bloodstream infections

Background: Health care-associated infections (HAIs) are avoidable through good hand hygiene (HH) practices. Hand hygiene compliance systems (HHCSs) have been shown to reliably measure HH adherence, but data on their effectiveness at reducing HAI rates are limited.
Methods: This nonrandomized, pre-post intervention study was conducted at a community hospital in the United States. HAI rates were examined before and after implementation of a HHCS. Preintervention began in January 2014 and intervention began in March 2015; data were collected through September 2017. Additional infection-specific interventions were carried out. HAIs were calculated as incidence rate ratios.
Results: The preintervention and intervention periods included 14,297 and 36,890 patients, respectively. The HHCS recorded an average of 696,928 HH opportunities/month. A significant reduction in the rate of catheter-associated urinary tract infections was observed during the intervention: IRR, 0.55; 95% CI, 0.35-0.87. Similarly, a significant reduction in the rate of central line-associated bloodstream infections was observed: IRR, 0.45; 95% CI, 0.23-0.89.
Discussion and conclusions: These findings suggest that monitoring HH practices with an automated system, in addition to other infection control measures, may be an effective means of reducing HAIs. Further studies are needed to isolate the potential role of HHCSs in the reduction of HAIs.

Health care-associated infections (HAIs) continue to threaten the health and safety of patients in US hospitals[1] and remain an economic burden to the health care system.[2] The Centers for Disease Control and Prevention (CDC) estimates that during a hospital stay, approximately 1 in 25 patients contracts at least 1 HAI.[1] Catheter-associated urinary tract infections (CAUTIs) and central line-associated bloodstream infections (CLABSIs) are among the 5 HAIs considered to have the highest influence on the health care system.[2] CLABSIs are among the most expensive HAIs, with an estimated cost of $45,814 per case; CLABSIs due to methicillin-resistant *Staphylococcus aureus* have been estimated at $58,614 per case.[2]

To prevent HAIs, good hand hygiene (HH) practices have been supported by the CDC, The Joint Commission, and the World Health Organization (WHO).[1,3,4] The CDC defines HH as "the practice of cleaning hands to prevent the spread of disease-causing germs."[1] Although effective HH is considered the most important way to prevent pathogen transmission in health care settings, adherence to proper HH practices has remained low.[4] In addition, HH compliance (HHC) is often difficult to measure.[5]

The WHO considers direct observation to be the gold standard for measuring HHC.[4] This method, which requires uniform observer training, can be both labor intensive and expensive, and it can impinge on patient privacy rights.[4] Direct observation has also been shown to influence the behavior of health care workers yielding inaccurate measures of real-world HHC.[4] These limitations may be overcome with the use of an automated HHC system (HHCS). In a previous pilot study conducted in 2 hospital units, we reported that an automated HHCS is a reliable means of measuring HHC.[6] Compared with human observers, an automated HHCS captured significantly more HH opportunities and ensured that the hospital reached its HHC goal of 95%. There was also a trend toward fewer

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E-mail address: smccalla@wphospital.org (S. McCalla).
Conflicts of interest: None to report
Biovigil Healthcare Systems Inc acted as a repository for the hospital's hand hygiene surveillance and compliance data and provided customized data analysis to support the study.

0196-6553/
https://doi.org/10.1016/j.ajic.2018.05.017

HAIs during the HHCS intervention period.[6] Following that pilot study, we expanded the use of the automated HHCS from 2 units to all hospital units. In the present study, our aim was to examine the association between this hospitalwide implementation of an automated HHCS and the rate of HAIs, including CAUTIs and CLABSIs.

METHODS

Ethics approval

This study was exempt from institutional review board review and informed consent protocols.

Study site

This single-site study was carried out at a 292-bed community hospital in White Plains, NY.

This suburban hospital is a nursing Magnet facility located near a large metropolitan area and serves as the tertiary hub for a large health care system. To improve the hospital's HHC rate and meet its goal of 95% for HHC, an automated HHCS was previously tested in a pilot study carried out in the hospital's intensive care unit (ICU) and ICU stepdown unit that included caregivers who had direct patient contact.[6] Following that pilot, the automated HHCS was adopted long-term and expanded to all unit caregivers with direct patient contact.

Hospital leadership fostered a strong culture of HHC, empowering staff to intervene if noncompliance was observed. In addition, user-level compliance data were used to reinforce efforts to improve HHC. To accommodate a learning curve for hospitalwide adoption of the automated HHCS, the initial expectation for HHC was 90%. Beginning in January 2017, management raised expectations to the previously established goal of 95% compliance. Through real-time intervention and feedback from management, compliance behavior was improved and sustained throughout the study period.

Study design

The goal of this nonrandomized, pre–post intervention study was to determine whether implementing a hospitalwide automated HHCS was associated with reduced rates of HAIs. From January 2014-September 2017, data were collected from de-identified electronic medical records, routine hospital infection surveillance, and the HHCS repository. From January-December 2014, human observers were used to measure HHC in all hospital units, as described previously.[6] Human observation of HHC was continued through February 2015, and in the present study, these 14 months were part of the preintervention period. The automated HHCS was partially implemented from March-October 2015. Beginning in November 2015, the automated HHCS was fully implemented throughout the hospital, except in the emergency department, and data were collected through September 2017. The automated HHCS was implemented in the following units: ICU and ICU stepdown; medical-surgical stepdown; critical care unit and critical care stepdown; labor and delivery; maternity; neonatal ICU; and medical-surgical units, including orthopedics, oncology, and pediatrics. The automated HHCS was not implemented in operating rooms and other procedure areas. During March 2016, the automated HHCS was implemented in the emergency department. During April 2017, a contact precautions protocol was enabled on the automated HHCS in which caregivers were prompted to wash their hands at a sink instead of using alcohol sanitizer after exiting a room designated as contact plus.

Participants

All patients who were in units that implemented the automated HHCS were included in the study. All unit caregivers with direct patient contact were required to use the automated HHCS. This included nurses, respiratory therapists, care managers, physicians, dietary aides, transporters, registrars, physical therapists, housekeeping staff, and technicians (radiology and cardiology).

HHCS

The Biovigil automated HHCS (Biovigil Healthcare Systems Inc, Ann Arbor, MI) consists of a wearable device that reminds caregivers to carry out HH.[6] A yellow and then red light on the device shines until hand hygiene is performed, at which point the light shines green, assuring patients and anyone at the bedside that HHC was performed. The device validates HHC through the detection of alcohol on the hands of caregivers by a chemical sensor. The device can also validate handwashing with soap and water through detection of the proximity of and time spent at a sink. Additional details about this automated system have been previously published.[6]

Other interventions

During this study, other infection control interventions were implemented in the hospital. Figure 1 summarizes relevant interventions by infection type. In addition to these interventions, general training occurred during the study period to reinforce established hospital policies. Training on Foley catheter insertion and maintenance was carried out in May 2014, and training on central line insertion and maintenance was carried out in August 2014 and January 2016.

HHC rates

Throughout the study, HHC was measured at 2 indications: upon entering patient rooms and after exiting patient rooms. HH opportunities and HH events were recorded by each caregiver's device and data were generated and stored on cloud computing-based applications. HHC was calculated as the number of HH events divided by the number of HH opportunities.

Infection rates

Data on the number of CAUTIs and CLABSIs were collected by routine hospital infection surveillance per the CDC National Healthcare Safety Network protocols. CAUTIs and CLABSIs were defined as previously described.[6] CAUTI rates were calculated as the number of CAUTIs divided by catheter days multiplied by 1,000. CLABSI rates were calculated as the number of CLABSIs divided by central line or umbilical cord catheter days multiplied by 1,000.

To accommodate the staggered phase-in of the HHCS, units were included in either the preintervention or intervention periods based on their implementation of the HHCS.

Statistical analysis

Patient demographic data were represented as total numbers and percentages and medians and ranges. CAUTI and CLABSI rates were represented as incidence rate ratios with 95% confidence intervals (CIs). Units with no history of CAUTIs or CLABSIs were not

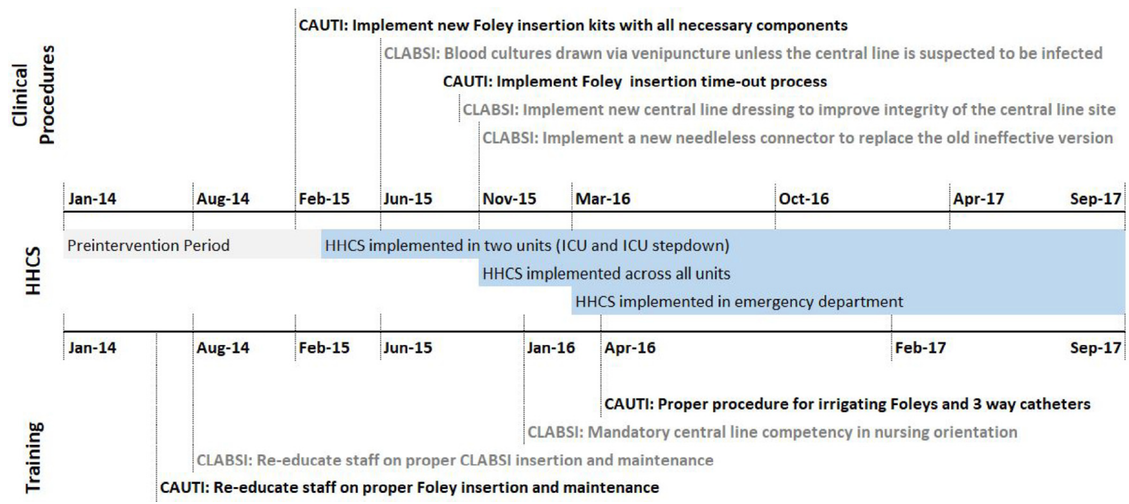

Fig 1. Timeline of notable infection control interventions implemented during the study for catheter-associated urinary tract infections and central line-associated bloodstream infections, January 2014-September 2017. *CAUTI*, catheter-associated urinary tract infection; *CLABSI*, central line-associated bloodstream infection; *HHCS*, hand hygiene compliance system; *ICU*, intensive care unit.

included in the incidence rate analyses. This included labor and delivery, maternity, and the neonatal ICU for CAUTIs and medical-surgical pediatrics, labor and delivery, maternity, and the neonatal ICU for CLABSIs.

RESULTS

Patient demographic characteristics

Characteristics of the patient population before and after implementation of the automated HHCS are shown in Table 1. The number of patients during the preintervention and intervention periods was 14,297 and 36,890, respectively. The age and major diagnostic categories of patients were similar during the preintervention and intervention periods.

HHC

HH opportunities and actual HH events were recorded by the automated HHCS both when caregivers entered patient rooms and after they left patient rooms. Figure 2 shows the total HH opportunities per month, as recorded by the automated HHCS during the intervention period. HH opportunities grew from 60,167 in March 2015 when the automated HHCS was implemented only in the ICU and ICU stepdown unit to 779,824 in July 2016 when the system was fully implemented throughout the hospital. The average HH opportunities per month was 696,928 during full implementation (March 2016-September 2017). On average, the HHC rate during the intervention period was 95.3% (Figure 2).

HH reminders were enabled on the HHCS. The use of reminders was associated with an increased number of HH events upon room entry (Figure 3). Although most HH events occurred within 13 seconds of room entry, a reminder tone on the HHCS device at 14 seconds prompted a second, yet smaller peak in HH events. This trend toward an increase in HH activity following reminder tones was also observed with reminders at 29 and 42 seconds after room entry.

Table 1
Patient demographic characteristics in all hospital units that implemented the hand hygiene compliance system, January 2014-September 2017

Characteristic	Preintervention January 2014-February 2015	Intervention March 2015-September 2017
Total patients	14,297	36,890
Female	7,777 (54.4)	20,140 (54.6)
Male	6,520 (45.6)	16,750 (45.4)
Age, y	67 (1-106)	68 (1-108)
Top-5 major diagnostic categories		
Cardiology/arterial disease	2,428 (17.0)	5,739 (15.7)
Gastroenterology	2,099 (14.7)	5,247 (14.4)
Pulmonology	1,447 (10.1)	3,689 (10.1)
Infectious disease	1,229 (8.6)	3,271 (9.0)
General surgical	1,029 (7.2)	2,641 (7.2)

NOTE. Values are presented as n (%) or median (range).

HAI rates

The rates of CAUTIs and CLABSIs were recorded in all units before and after implementation of the automated HHCS. During the preintervention period, the rate of CAUTIs was 2.20 per 1,000 catheter days (Table 2). This rate decreased to 1.21 per 1,000 catheter days during the intervention period, representing an almost 45% relative risk reduction (RRR) in CAUTIs (RRR, 44.8%; 95% CI, 12.7%-65.2%). The total number of CAUTIs observed was 46 during the preintervention period and 30 during the intervention, and the number of catheter days was 20,919 and 24,730, respectively. See Figure 4 for a time series of CAUTIs across the study periods.

The introduction of a new Foley catheter insertion kit during February 2015 (see Figure 1) overlapped with the pilot study of the automated HHCS in the ICU and ICU stepdown unit.[6] Due to staggered implementation of the HHCS throughout the hospital, a Foley catheter insertion kit control group emerged. This control group contained units that had the Foley intervention for up to 7 months before the automated HHCS was initiated. The rate of CAUTIs in this Foley control group was lower than the CAUTI rate observed before the Foley intervention, and the CAUTI rate decreased further after implementation of the HHCS (Table 3).

The rate of CLABSIs during the preintervention period was 1.43 per 1,000 central line days; during the intervention period, the CLABSI rate was 0.64 per 1,000 central line days (Table 2). The RRR for CLABSIs was almost 55% (RRR, 54.9%; 95% CI, 10.7%-77.3%). There were 26 CLABSIs during the preintervention period and 12 during the intervention, and the number of central line days was 18,163 and 18,605, respectively. See Figure 5 for a time series of CLABSIs across the study periods.

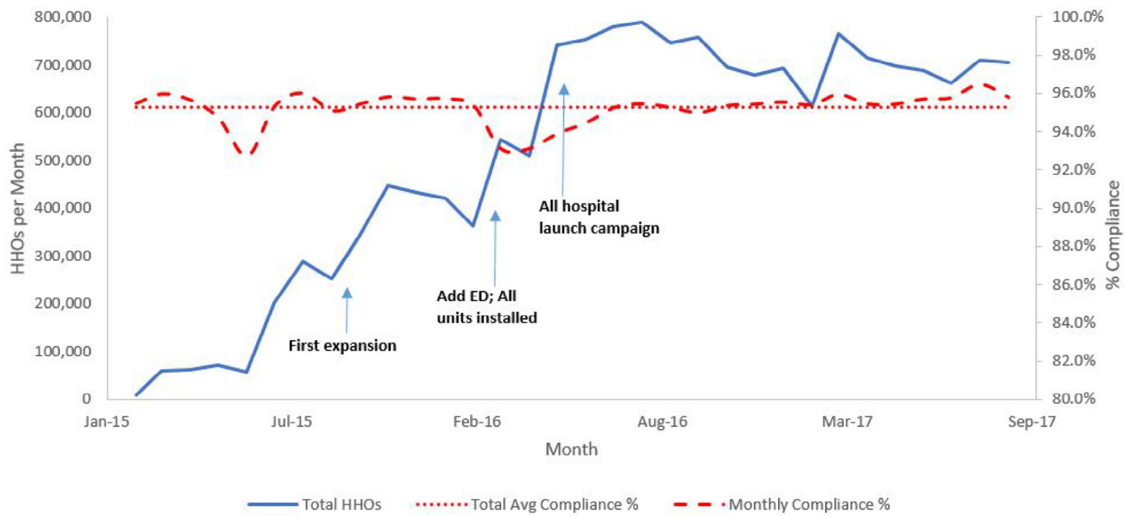

Fig 2. Total hand hygiene opportunities and total hand hygiene compliance, February 2015-September 2017. *ED*, emergency department; *HHOs*, hand hygiene opportunities.

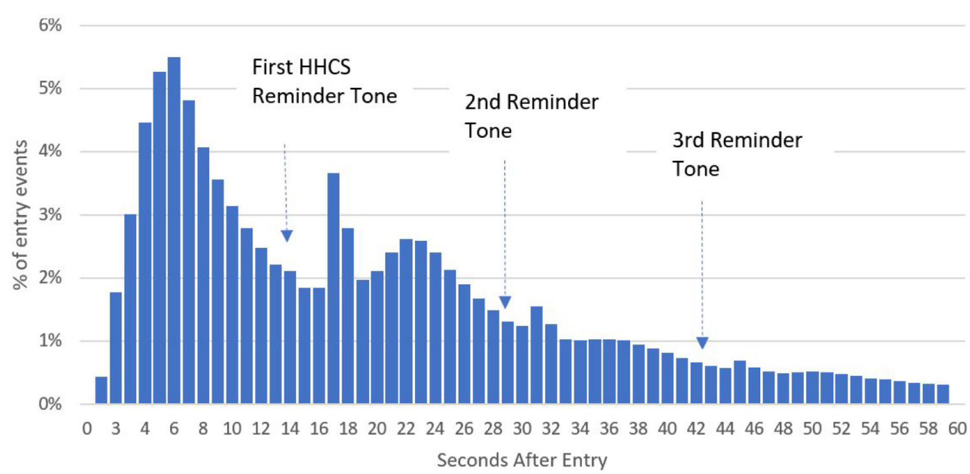

Fig 3. Time to perform hand hygiene after room entry. *HHCS*, hand hygiene compliance system.

Table 2
Hospital-acquired infections, January 2014-September 2017

Infection*	Preintervention†	Intervention†	Incidence rate ratio (95% confidence interval)
Catheter-associated urinary tract infection	2.20	1.21	0.55 (0.35-0.87)
Central line-associated bloodstream infection	1.43	0.64	0.45 (0.23-0.89)

*Infections per 1,000 catheter days for catheter-associated urinary tract infections and infections per 1,000 central line days for central line-associated bloodstream infections.
†Units were included in the preintervention or intervention periods based on their implementation of the hand hygiene compliance system.

Table 3
Rate of catheter-associated urinary tract infections in the Foley catheter control group

Unit	Before both interventions January 2014-February 2015	Foley catheter only March 2015-October 2015	After automated HHCS and Foley catheter November 2015-September 2017
Study units	2.01	1.58	1.15

HHCS, hand hygiene compliance system.

DISCUSSION

We have shown that use of an automated HHCS, in addition to other interventions, is associated with significant reductions in the rate of CAUTIs and CLABSIs. A decrease of almost 45% in the relative risk of CAUTIs occurred during the 32-month HHCS intervention. A new Foley catheter insertion kit was implemented in the hospital during the intervention period. Although the new Foley kits may have played a role in the observed decrease in CAUTIs, we found that the greatest decrease in the CAUTI rate occurred during

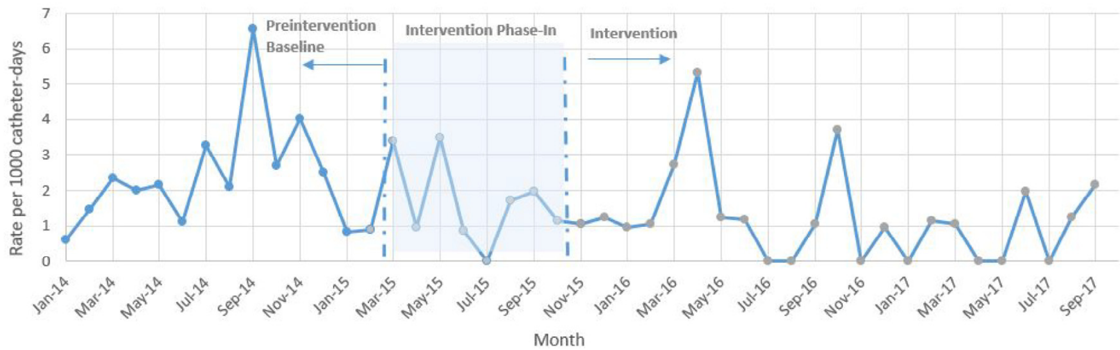

Fig 4. Infection rate time series for catheter-associated urinary tract infections.

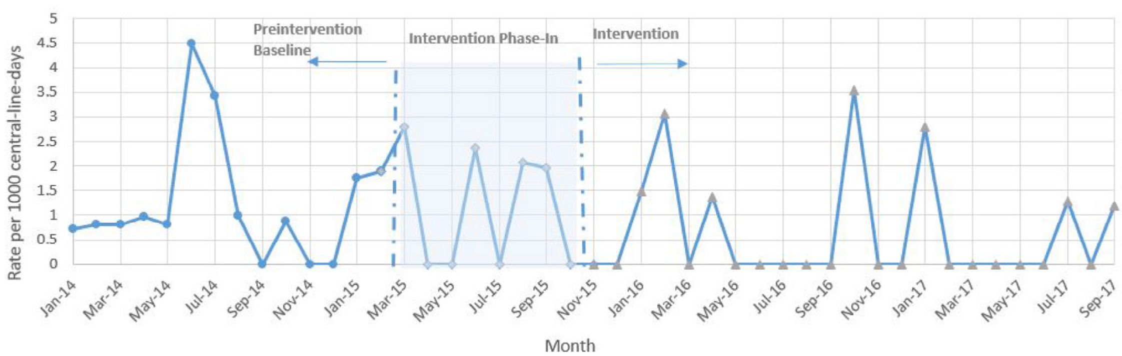

Fig 5. Infection rate time series for central line-associated bloodstream infections.

concomitant implementation of the Foley kits and the automated HHCS.

We observed a reduction of almost 55% in the relative risk of CLABSIs during the HHCS intervention. Several other interventions occurred during the study that may have contributed to the decrease in infections. Notable CLABSI interventions occurred before the partial implementation of the automated HHCS and again around the time of full implementation. Although we would expect a hospitalwide rollout of the automated HHCS to have an influence on the incidence of CLABSIs, we cannot entirely rule out the influence of the additional CLABSI-specific interventions that occurred during the study. We have previously demonstrated a trend toward decreased HAIs, including CLABSIs and infections due to multidrug-resistant organisms (MDROs), following implementation of the automated HHCS in 2 units.[6] Although reductions in the rate of HAIs did not reach statistical significance in that previous pilot study, we observed significant reductions in the rate of CAUTIs and CLABSIs in the present study, in which the use of the HHCS was expanded to all hospital units and the follow-up time for examining HAI rates was extended.

The automated HHCS is equipped with a reminder system that prompts caregivers to complete HH when HH opportunities occur. We have shown that this reminder system may help to improve HHC because there was a trend toward increased HH activity following reminder tones. The HH events in this analysis were limited to room entries in which the caregiver spent more than 60 seconds in the room because a new HH event was required upon exit and reentry in accordance with workflow rules.

In US hospitals, attributable costs for CAUTIs and CLABSIs have been estimated at $896 and $45,814 per case, respectively.[2] CLABSIs were the most expensive infections among the HAIs examined, including surgical site infections, ventilator-associated pneumonia, and *Clostridium difficile* infections. In our study, implementation of a hospitalwide automated HHCS, along with other CAUTI- and CLABSI-specific interventions, was associated with 16 fewer CAUTIs and 14 fewer CLABSIs by the end of the study period. Preventing these infections would translate to a potential cost savings of $655,732.

During this study, we did not observe a change in the rate of *C difficile* infections. A contact precautions protocol was implemented with the automated HHCS to modify HH for rooms designated as contact plus. Handwashing at a sink was required after exiting contact plus rooms. This protocol began in April 2017, 25 months after the start of the automated HHCS. Thus, our dataset includes only 5 months of follow-up, which includes time for staff to acclimate to the protocol. Longer follow-up may be needed to observe a decrease in *C difficile* infections.

A limitation of this study is its quasiexperimental design, which lacks randomization. In addition, due to other interventions, we were not able to completely isolate the influence of the automated HHCS on HAI rates. This is always a challenge because hospitals are dynamic environments and interventions are not likely to occur in the absence of other changes. Another potential limitation of this study is that HHC was measured at only 2 of the 5 WHO moments for HH (before patient contact and after patient contact)[4]; thus, we have not captured the potential role of the WHO HH moments that may be more directly associated with the care of indwelling medical devices (eg, before aseptic task and after body fluid exposure risk). We previously reported a decrease in infections due to MDROs following implementation of the HHCS.[6] In the present study, we were unable to examine MDROs due to internal process changes in MDRO surveillance that took place during the study; thus, slightly different reporting standards were used to measure the infection rates for MDROs before and after the HHCS intervention.

Although several studies have demonstrated an association between the use of an automated HHCS and increased rates of HHC,[7] few have examined the association between the use of these systems and HAI rates. Our findings suggest that an automated HHCS in combination with hospital infection control measures may be an effective means to reduce HAIs. Future studies are needed to validate these findings and to assess the cost-effectiveness of the use of automated systems to monitor and improve HHC.

Acknowledgments

The authors thank the hospital Board of Directors and executive leadership for their recommendation and support of the hand hygiene compliance system, members of the Hand Hygiene Task Force, and Ruth Mulrane for assistance with the collection of patient demographic data. The authors also thank Theresa E. Singleton, PhD, Singleton Science LLC, for providing medical writing support, which was funded by Biovigil Healthcare Systems Inc, in accordance with Good Publication Practice guidelines.

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